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A MODEL FOR EVALUATING HS/HSL COMMUNITY CONSOLIDATION

by

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A MODEL FOR EVALUATING HS/HSL COMMUNITY CONSOLIDATION

by

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ABSTRACT

A methodology is developed to assist in the evaluation of competing proposals for HS/HSL consolidation. Six criteria are developed to allow a quantitative measure of critical personnel, cost and operational issues. The criteria are incorporated into a spreadsheet model that can evaluate five options simultaneously. Decision maker participation is required to derive a set of weights that represent the relative importance attributed to each criteria. Five options currently under consideration as candidates for consolidation are examined. Analysis is conducted to determine the effect different weight values have on the determination of the optimal solution. A sample run of the model is conducted to demonstrate its use .

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EXECUTIVE SUMMARY

Tactical helicopters in the United States Navy are divided into two different type of communities, Helicopter Antisubmarine (HS) squadrons and Helicopter Antisubmarine (Light) (HSL) squadrons. Both of these squadron types were developed during the Cold War and tailored to meet the Soviet naval threat of that time. With the breakup of the USSR, the perceived reduction of a blue water submarine threat, and the Navy's new focus on littoral warfare, many of those threats appear no longer valid. These changes, together with pressure to reduce the military budget and the expected introduction of a common helicopter, the SH-60R, have lead to an effort to consolidate these two communities.

A working group was established to study the future structure and organization of a consolidated HS and HSL community. A proposal was developed by the LAMPS and CV helicopter requirements offices in the Pentagon. The proposal is called "Big Sky" and presents three possible HS/HSL consolidation structures. Manpower costs have been computed for each of the three options presented in the Big Sky proposal, however, no analysis has been conducted to assess the impact each of the three options may have on mission performance and operational requirements.

This thesis develops a methodology that allows the evaluation of competing HS/HSL consolidation options. Six important issues are identified that could be adversely affected by HS/HSL consolidation. Appropriate measures of effectiveness are developed for each issue. The issues are; manpower costs, effective use of LAMPS assets, fulfillment of aircraft carrier requirements, command opportunity, detachment scheduling concerns, and ability to meet forward basing requirements. The criteria are incorporated into a spreadsheet format, resulting in a model that allows the comparison of five different consolidation options simultaneously.

Decision maker participation is required to develop a set of weights that determine the relative importance attributed to each criterion. Manpower cost is considered a

constraint, and the remaining five criteria are combined as the measure of effectiveness for an option.

The three Big Sky options and two earlier consolidation proposals are evaluated by the model. A summary of the different characteristics for the five options examined is presented in the following table:

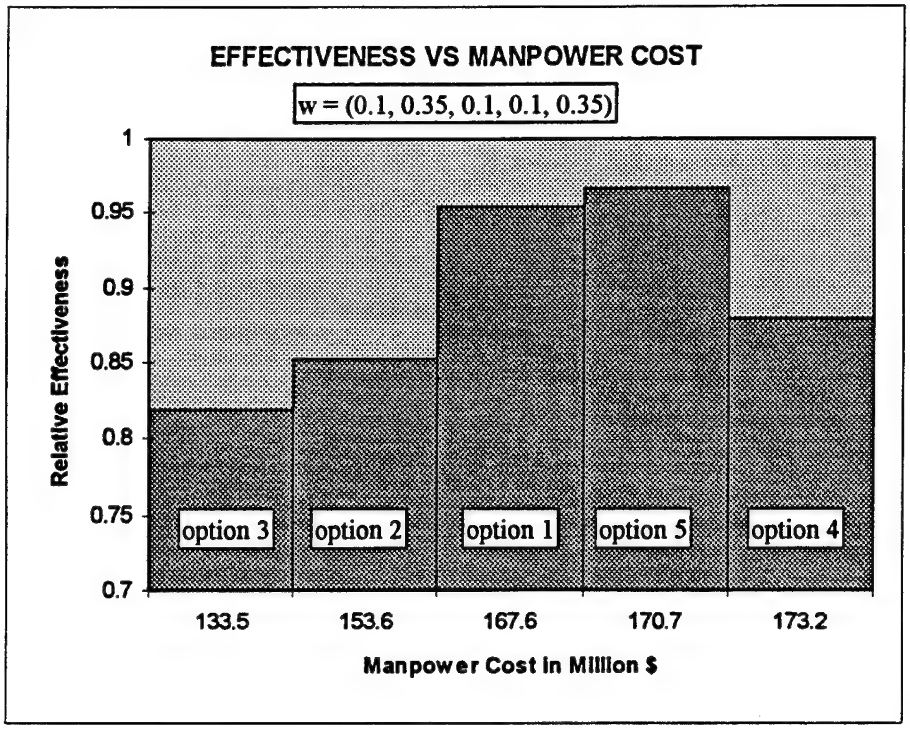
	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
# HSL SQUADRONS	6	2	0	10	10
# HS SQUADRONS	10	10	10	0	10
# CS SQUADRONS	0	0	0	4	0

CS squadrons are shore-based HS squadrons. The model computes criterion values for each of the options evaluated, and the results are presented in a table. An example of the results table produced by the model is shown below:

CRITERION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	0.8	0.6	0.5	0.7	1
Total Coverage	1	1	0.8	1	1
Manpower Costs	0.8	0.87	1	0.77	0.78
CV Helo Availability	0.67	0.67	1	0.67	0.67
Detachment Separation Time	1	1	0.5	1	1
Total Forward Basing	1	0.75	0.92	0.9	1

A value of 1.0 signifies that the option achieved the highest criteria value for the set of options considered. A value less than one gives criterion value achieved as a fraction of the maximum.

A set of criteria weights is developed, with decision maker help, and used by the model to compute the overall level of effectiveness achieved by an option. A graph of option effectiveness for a given set of weights versus the associated manpower cost can be produced. An example of the resulting graph is shown below:



The graph allows a decision maker to determine the option that yields the highest level of effectiveness for a given cost.

Five different sets of criterion weights are developed and used to determine the effect that different sets have on the solution selected by the model. Graphs of option effectiveness versus the associated manpower for each of the five sets of weights are presented. Additionally, a sample run of the model is performed to demonstrate its use by a decision maker.

I. INTRODUCTION

Tactical helicopters in the United States Navy are divided into two different type of communities, Helicopter Antisubmarine (HS) squadrons and Helicopter Antisubmarine (Light) (HSL) squadrons. Both of these squadron types were developed during the Cold War and tailored to meet the Soviet naval threat of that time. With the breakup of the USSR, many of those threats are no longer valid. Furthermore, new threats and missions have arisen which require less specialization. These changes, together with pressure to reduce the military budget, have lead to an effort to consolidate these two communities.

A. HSL SQUADRONS

HSL squadrons provide air capable frigates, destroyers and cruisers with single and dual aircraft detachments. Each detachment consists of four to six pilots and between 15 and 22 maintenance personnel. When deployed aboard a ship, the helicopter becomes an integral part of the ship's weapon system. Its primary missions are anti-submarine warfare (ASW) and anti-ship surveillance and targeting (ASST). Secondary missions include search and rescue (SAR), logistic support and communications relay. When deployed, a detachment is under the operational control of the ship's commanding officer and under the administrative control of the parent squadron.

The organization of an HSL squadron reflects its detachment oriented mission requirements. A typical squadron has 13 helicopters and approximately 250 personnel, 50 officers and 200 enlisted. The squadron has a shore based component of personnel that does not deploy in addition to a sea going, or deployable, component from which detachments are formed. The shore based component provides administrative support to deployed detachments.

HSL squadrons operate the SH-60B helicopter, a modified version of the Army's UH-60 Black Hawk. It is equipped with an APS-124 surface search radar, forward-looking infrared (FLIR) equipment and an ALQ-142 electronic surveillance measures (ESM) sensor for its ASST missions. ASW sensors include a sono-buoy dispenser, ASQ-

81 magnetic anomaly detector (MAD) and a UYS-1 acoustic processor. A AN/ARQ-44 data link allows secure transmission of sensor data to the ship. Weapon systems for the SH-60B include the Mk-46 and Mk-50 ASW torpedoes, the Penguin anti-shipping missile and a door mounted 7.62 mm M-60 machine-gun. Because of its diverse mission capabilities, the Navy has designated the SH-60B helicopter as LAMPS for "Light Airborne Multi-purpose System".

B. HS SQUADRONS

HS squadrons operate the SH-60F helicopter, also a modified UH-60 Black Hawk. The SH-60F is equipped with an AN/AQS-13F dipping sonar, ASQ-81 MAD and can carry the Mk-46 and Mk-50 ASW torpedoes. Unlike the SH-60B, the SH-60F is not equipped with a surface search radar, a data link system or an ESM suite, giving it very limited ASST capabilities. Since 1990, HS squadrons began deploying with the HH-60H in addition to the SH-60F. The HH-60H is the combat SAR (CSAR) and special warfare operations variant of the H-60 helicopter family. The HH-60H is equipped with ALQ-144 infrared jammers, chaff and flare dispensers and two 7.62 mm M-60D machine guns for self defense, and can carry up to eight Navy SEALs.

The primary mission of an HS squadron is to provide inner zone ASW protection to the aircraft carrier. The inner zone is defined as the area within a 50 nautical mile radius of the carrier. Outer zone protection is provided by the carrier's escort ships and their SH-60B assets. The HS squadrons are also tasked with plane guard and SAR duties as well as providing logistic support to the carrier. The addition of the HH-60H gives the carrier CSAR and special warfare capabilities.

A typical HS squadron contains six SH-60F helicopters and 200 personnel, of which approximately 30 are officers and the remaining are enlisted. An HS squadron may be assigned two HH-60H helicopters that are flown by pilots trained in both the F and H models. The entire HS squadron embarks on the carrier when it deploys, therefore, there is no shore component. The squadron's commanding officer retains both operational and administrative control at all times.

C. THE SH-60R

The SH-60R is currently under development and expected to enter service in 2002. It is the planned replacement for the SH-60B and SH-60F. Equipped with radar, ESM, FLIR and a dipping sonar, the SH-60R will be capable of performing both the HS and HSL missions. Addition of a inverse synthetic aperture radar (ISAR) and ALF dipping sonar will increase ASST and ASW mission capabilities over those of the SH-60B and SH-60F. The SH-60R will also be equipped with the Hell Fire air to surface missile system in addition to the Penguin missile and ASW torpedoes, greatly enhancing the parent ship's defense against small, fast attack boats.

The addition of the SH-60R to the fleet will allow the Navy to operate two variants of the same airframe in the tactical helicopter role, the SH-60R and HH-60H. A reduction in the number of different helicopter types will reduce operating and maintenance costs by reducing supply and maintenance infra-structure. In addition, Fleet Replacement Squadrons (FRS) for the HS and HSL communities can be combined since they will be operating the same type of aircraft. A study of FRS consolidation in the A-6 community shows that economic savings and reduced support requirements can be achieved (Kelley, 1978). Currently there are four FRS squadrons, one HS and one HSL FRS on each coast. Consolidation could reduce the total number of FRS squadrons from four, two on each coast, to two.

D. CONSOLIDATION

The tactics and organization of HS and HSL squadrons were developed over the years with the primary mission of protecting the carrier battle group from the threat of Soviet nuclear attack submarines in the open ocean. The perceived reduction of a blue water submarine threat to the carrier, as well as the Navy's new focus on littoral warfare, are bringing HS and HSL mission requirements closer together. This trend, together with the expected introduction of a common helicopter, the SH-60R, raises the question of consolidating the HS and HSL squadrons into a single community.

A message from RADM Dirren to Helicopter Type Wing Commanders prompted the establishment of a working group to study the future structure and organization of a consolidated HS and HSL community. A proposal was developed by N-880E, the LAMPS requirements office in the Pentagon. The proposal is called "Big Sky" and presents three possible HS/HSL consolidation structures.

The first option consists of six HSL squadrons each with ten SH-60R helicopters and ten HS squadrons each with four SH-60R and four HH-60H helicopters. The HS squadron will provide four HH-60H to the carrier and four one-plane SH-60R detachments to the battle group's escorts. The HSL squadrons will provide additional SH-60Rs if needed and support ships not assigned to a carrier battle group.

The second option also has ten HS squadrons with four SH-60R and four HH-60H helicopters per squadron, but all HSL assets are combined into two "super squadrons" each with 20 SH-60Rs. The HS squadrons will provide the carrier with four HH-60Hs and one two-plane and four one-plane detachments to the escorts. The HSL mission is the same as in the first option.

The final proposal abandons the HSL concept, having only ten HS squadrons with ten SH-60R and four HH-60H helicopters per squadron. Four HH-60H and two SH-60R would be based on the carrier. Three two-plane and two one-plane detachments would be based on the escorts. Helicopter requirements by ships not assigned to a carrier battle group would be provided by non-deployed squadrons. The three Big Sky proposals are summarized in Table 1.

	OPTION 1	OPTION 2	OPTION 3
# HSL SQUADRONS	6	2	0
SH-60R's per squad.	10	20	0
HH-60H's per squad.	0	0	0
# HS SQUADRONS	10	10	10
SH-60R's per squad.	4	6	10
HH-60H's per squad.	4	4	4
SH-60R's on CV	0	0	2
HH-60H's on CV	4	4	4

Table 1. Big Sky Proposals.

Manpower costs have been computed for each of the three options presented in the Big Sky proposal. However, no analysis has been conducted to assess the impact the three options may have on mission performance and operational requirements. N-880E has expressed concern that manpower alone will drive the decision as to which option to adopt without any regard to mission and operational effectiveness issues. This thesis addresses this concern by developing a model that allows the comparison of different options along six sets of mission effectiveness, operational requirement and manpower cost criteria. The model utilizes decision analysis to evaluate the relative importance of each criterion and identifies the option with the optimal value.

The selection and development of the criteria and the general structure of the model are explained in Chapter II. Chapter III introduces decision analysis and explains its application to the model. A sample run of the model is discussed in Chapter IV. Conclusions and recommendations are presented in Chapter V.

II. CRITERIA SELECTION AND DEVELOPMENT

A. MODEL BACKGROUND

A model is developed to evaluate five different options simultaneously. The model is constructed in a spreadsheet format using Microsoft Excel 5.0. This software package is selected because of its wide spread use within the Navy.

Each option is evaluated using six criteria. A criterion is defined as a measure of effectiveness and provides the basis for evaluation (Zionts, 1970). The criteria can be grouped into three broad categories: manpower issues and costs, mission effectiveness and fleet support requirements. Each criterion and its formulation will be covered in detail in the following section.

Several general assumptions were made to facilitate the HS/HSL consolidation study (Dirren, 1993). These assumptions are:

- ASW helicopters will be part of the carrier battle group.
- Procurement will occur as projected by recent N8 decisions.
- The SH-60R will be the common ASW/Tactical helicopter for both HS and HSL communities.
- The carrier battle group will be sized with one carrier and from five to seven air capable surface combatants.
- All missions must support From The Sea strategy.

N8 is the Deputy Chief for Naval Operations for resources, warfare requirements and assessments in the Pentagon, and is responsible for developing aircraft procurement plans. Since the study group message was issued, procurement plans have undergone numerous revisions. In the Big Sky proposal, N880E assumes that there will be 100 SH-60Rs and 40 HH-60Hs in the operational fleet. These aircraft numbers, together with the assumptions presented above, are incorporated into the model and used in the development of the six criteria.

B. CRITERIA FORMULATION

Six important issues are identified that could be adversely affected by HS/HSL consolidation. An appropriate measure of effectiveness (MOE) or criterion must be developed for each issue to allow the evaluation and comparison of different HS/HSL consolidation proposals. The issues are: manpower costs, effective use of LAMPS assets, fulfillment of aircraft carrier helicopter requirements, command opportunity, detachment scheduling concerns and ability to meet forward basing requirements.

In the Big Sky study, manpower costs were computed for the different options; however, no criteria were identified or developed for the other five issues . Criteria are developed here to quantitatively measure the remaining issues. The criteria are incorporated into a spreadsheet format, resulting in a model which allows the comparison of different options and an evaluation of an individual option's overall value.

1. Command Opportunity

In a study which consisted of interviews of HS and HSL commanding officers who were asked what concerned them most about HS/HSL consolidation, command opportunity was unanimously selected as a topic of great concern (Roll, 1994, pp. 34). A majority of the commanding officers also expressed concern over the loss of squadron command opportunity on the carrier (Roll, 1994, pp. 33). This is traditionally viewed as an important path to flag rank. One option presented for HS/HSL consolidation, not part of the Big Sky proposal, suggests shore-based HS squadrons which send detachments to the carrier. This option would lead to a loss of all squadron commands on the carrier.

Command opportunity for option i, CO_i, is computed in the model by adding the total number of commands billets available. This is accomplished using the following equation:

$$CO_i = T_{i,HSL} + T_{i,CS} + w * T_{i,HS} \qquad (1)$$

where: $T_{i,t}$ is the total number of squadrons of type t for option i, for i=1,...,5 and $t \in \{HSL, HS, CS\}$

w is the non-carrier to carrier command trade-off weight.

The subscript t accounts for the fact that there are three different type of squadrons possible: traditional HSL squadrons denoted by t = HSL, traditional HS squadrons denoted by t = HS and shore-based HS squadrons that deploy detachments denoted by t = CS. The equation returns the equivalent total number of command billets per option. The trade-off weight w (a number greater than 1) is used to express the desirability of a carrier squadron command over a non-carrier command, and will be discussed in detail in the following chapter.

2. Efficient Use of LAMPS Assets

The addition of helicopters to surface ships has greatly increased a ship's defensive and offensive capabilities. With its extensive array of passive and active sensors, a helicopter can extend the detection horizon of a surface ship by as much as 800% (Dahl, 1993). With a limited number of resources, the question arises as to which option maximizes the use of LAMPS assets. One way to measure this is to see how many air capable surface ships would put to sea without a helicopter. This is done by counting the number of empty "rails". The rail refers to the RAST recovery apparatus which allows the helicopter to land in heavy seas. Single rail ships can deploy with one helicopter, and dual rail ships with two helicopters. This is an adequate measure, however, it does not give any sense of the tactical value of a LAMPS helicopter.

The model developed in this thesis uses a different measure to assess the efficient use of LAMPS assets. One of the most widely used sensors on a LAMPS helicopter is its surface search radar. Most naval operations in recent years utilized surface ships primarily in the blockade role, where a helicopter-mounted radar greatly increases the amount of area controlled. A carrier deploys with several aircraft types equipped with surface search radar which have greater speed and range than a helicopter. For this reason, a helicopter's radar would be of little use to the carrier. Therefore, the model measures the total area of

radar coverage that can be achieved by the number of helicopters assigned to the LAMPS role.

The model first computes the total radar coverage that one helicopter can achieve on average in one hour. The radar coverage for a stationary helicopter is the area of a circle centered at the radar with a radius equal to the radar's range (R). For a moving helicopter with a velocity equal to V, the area of coverage in one hour elongates into a rectangle of length V and width of 2R, and is represented in Figure 1.

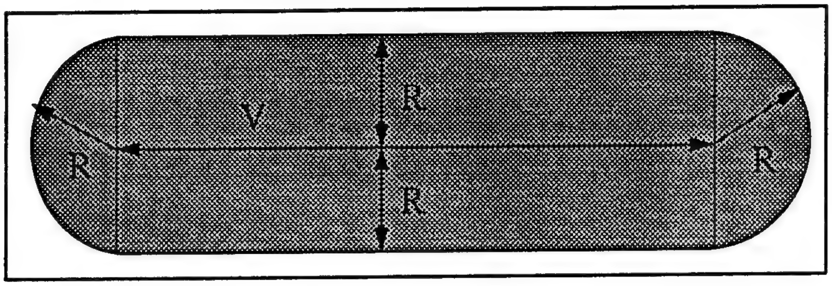


Figure 1. Radar Coverage Area.

The equation utilized to compute this is as follows:

$$T_{cov} = \sum_{j}\left(\pi * R_j^2 + 2 * V * R_j * TGT_j\right) \qquad (2)$$

where:

T_{cov}	is the total area of radar coverage in square miles per helicopter per hour
R_j	is the range of detection of a target of size j, for $j \in \{s, m, l\}$
V	is the speed the helicopter is traveling
TGT_j	is the probability of being tasked to search for a target of size j, for $j \in \{s, m, l\}$

For the purposes of this model, target sizes are classified as either small (j=s), patrol boat size, medium (j=m), frigate size, or large (j=l), merchant ship size. As the size of the target increases, the range at which the radar can detect it also increases. The value returned by Equation 2 is in square miles per helicopter per hour.

The number of LAMPS helicopters that can be deployed at any one time is then calculated by:

$$TLD_i = \min(T_{rails}, T_R - (T_{i,HS} * T_{i,R,HS})) \quad (3)$$

where: TLD_i is the total number of LAMPS helicopters deployed in option i, for i=1....,5
T_{rails} is the total number of rails deployed
T_R is the total number of SH-60R helicopters
$T_{i,HS}$ is the total number of HS squadrons in option i, for i=1,...,5
$T_{i,R,HS}$ is the number of SH-60R helicopters assigned to HS squadrons in option i, for i=1,...,5

The total number of helicopters assigned to surface ships less carriers is computed in Equation 3 by taking the total number of SH-60Rs in the inventory and subtracting all the SH-60Rs that would be deployed on the carrier for each option. By taking the minimum of this number and the total number of rails available, Equation 3 ensures that the number of helicopters available does not exceed the deck space available.

A total radar coverage area in square miles per day for each option i, TRC_i, is then computed by:

$$TRC_i = T_{cov} * FMC_R * TLD_i \quad (4)$$

where: T_{cov} is defined above
FMC_R is the full mission capable rate for SH-60R helicopters
FH_R is the total number of flight hours in a 24 hour period for SH-60R helicopters
TLD_i is defined above.

By employing radar coverage as a measure of the efficient use of LAMPS assets, it is possible to determine how the addition and removal of SH-60R helicopters from the LAMPS role affects the amount of area that can be patrolled. This gives a quantifiable measure of the tactical value of LAMPS assets.

3. Manpower Costs

Manpower costs for each of the three options presented in the Big Sky proposal were computed by the Bureau of Naval Personnel. Squadron manpower documents were produced for each option. These documents are very detailed manning studies that show every individual by rank and billet required by a squadron. These documents are then

used to calculate accurate manpower costs. Costs are given in millions of dollars per year for each option. These costs only represent the yearly costs of manning the squadrons, and do not include operation, maintenance, supply or other such costs associated with a squadron.

4. Carrier Helicopter Requirements

As discussed in Chapter I, aircraft carriers employ organic helicopter assets for a variety of missions. Some missions, such as ASW and CSAR, are important only when the carrier is conducting combat operations in a hostile environment. Plane guard, SAR and logistic support are missions that are necessary any time the carrier is streaming or conducting fixed wing flight operations whether in peace time or at war.

The ability to meet mission requirements is directly related to the number of helicopters the carrier has that are available to fly. This is a function of the number of helicopters embarked on the carrier, the percentage of time a helicopter is mechanically capable of performing the mission assigned and the total number of hours a helicopter can operate in a 24 hour period. In the model, the ability of option i to meet carrier helicopter requirements, CHR_i, is computed by the equation:

$$CHR_i = \sum_a T_{a,i} * FMC_a * FH_a \qquad (5)$$

where:

- $T_{a,i}$ is the total number of helicopters of type a embarked on the carrier for option i, for i=1,...,5 and $a \in \{R, H\}$
- FMC_a is the full mission capable rate for helicopters of type a, for $a \in \{R, H\}$
- FH_a is the total number of hours a helicopter of type a can fly in a 24 hour period, for $a \in \{R, H\}$.

The subscript a accounts for the fact that two different type of helicopters, SH-60Rs (subscript R) and HH-60Hs (subscript H), can be deployed. Equation 5 returns the total number of helicopter flight hours available in a 24 hour period for each option evaluated. The larger the number, the greater the requirement that can be meet.

5. Detachment Separation Time

Detachment separation time is defined as the maximum amount of time that a deployed detachment will be separated from its parent squadron. For traditional HS squadrons, there is no separation involved and this time is zero. HSL squadrons are shore based and do send detachments, and the separation time is equal to the maximum time that a detachment can be deployed. Currently, the maximum deployment time is approximately six months, and this number is used in the model to compute detachment separation time.

Detachment separation time is used in the model to identify options that would present deployment scheduling problems. For traditional HSL and HS squadrons, deployment scheduling is essentially straight forward. An HSL squadron receives a proposed deployment schedule from an air capable ship it is tasked to support and assigns an available detachment to that ship. An HS squadron is assigned to an carrier air wing which, in turn, is assigned to an aircraft carrier. The HS squadron's deployment schedule becomes that of the aircraft carrier.

For the type of squadron structure presented in the third option of the Big Sky proposal, scheduling becomes more complicated. As presented in Chapter I, this option abandons the HSL concept and has only ten HS type squadrons that must support carrier requirements and supply detachments to surface ships. The squadron both deploys and sends out detachments.

This type of a structure would not present a problem if the detachments were assigned to surface ships within the same battle group. However, over 60% of HSL detachments assigned to surface combatants operate independently of a carrier battle group. Furthermore, of the detachments that are assigned to a battle group, over 50% subsequently separate to conduct independent operations (McElhannon, 1994). A detachment could be sent out six months prior to the squadron's deployment. When the detachment completes its deployment, it would return to find its parent squadron deployed. This could result in a maximum separation time of 12 months instead of the

current six months. To prevent this, more careful planning and firmer deployment schedules would be needed.

The model identifies an option that presents scheduling difficulties through the following series of equations:

$$Y_{i,t} = \min(1, T_{i,t}) \qquad \text{for } t \in \{HSL, HS, CS\} \tag{6}$$

$$DS_{i,t} = Y_{i,t} * 6.0 \qquad \text{for } t \in \{HSL, CS\} \tag{7}$$

$$DS_{i,HS} = Y_{i,HS} * (1 - Y_{i,HSL}) * 12.0 \tag{8}$$

where:

- $T_{i,t}$ is defined in Equation 1
- $Y_{i,t}$ is a binary variable that takes on the values 0 if the total number of squadrons of type t for option i is 0, and 1 if the total number is 1 or greater, for i=1,...,5
- $DS_{i,t}$ is the total separation time for squadron type t in option i, for i=1,...,5.

Equation 6 returns a 0 or 1 for each of the three squadron types for each option. If an option has HSL or CS squadrons, Equation 7 will return a value of 6.0. This corresponds to the six month detachment separation time for these types of squadrons. If an option has no HSL squadrons but does have HS squadrons, then the HS squadrons will also have to send out detachments as well as deploy and Equation 8 will return a value of 12.0. The detachment separation time for option i, DST_i, is determined by

$$DST_i = \max_t (DS_{i,t}) \tag{9}$$

where $DS_{i,t}$ is defined above for i=1,...,5 and for $t \in \{HSL, HS, CS\}$. Equation 9 selects the maximum separation time for an option, and it is this value that will be used to evaluate the option.

6. Overseas Squadron Requirements

Savings in manpower costs can be achieved by reducing the number of squadrons. This is proposed to varying degrees in several of the consolidation options presented. A problem that arises as the total number of squadrons is decreased is that overseas basing

requirements may not be met. To compensate for the shortfall, squadrons will have to forward deploy detachments on TAD (Temporary Additional Duty) orders to support ships stationed overseas. This has proved costly in the past and the price may offset or exceed any manpower savings.

Squadrons are stationed in airfields close to the ships they are assigned to support. HS squadrons are stationed on the East and West coasts of the United States and overseas in Japan. HSL squadrons are stationed on the East and West coasts of the United States, Hawaii and Japan. In this model, base location sites are grouped into four geographic regions, the East coast (E), the West coast (W), Hawaii (H) and Japan (J). Each option is evaluated as to its ability to meet HS and HSL overseas basing requirements. Failure to meet basing requirements identifies options that could incur the additional expense of forward deploying detachments to meet support requirements.

a. HS Overseas Basing Requirements

A squadron-to-carrier support ratio is computed to determine how many carriers can be supported by the HS squadron structure proposed in each option. Current N8 planning sets the number of helicopters embarked on the carrier at four HH-60Hs by fiscal year 2002 (Squires, 1994). Using the N8 plan, the ratio is computed as follows:

$$R_i = \frac{4}{\sum_t T_{i,H,t}} \qquad (10)$$

where: R_i is the squadron/carrier support ratio in squadrons per carrier for option i, for i=1,...,5

$T_{i,H,t}$ is the total number of HH-60H helicopters assigned to squadrons of type t for option i, for i=1,...,5 and $t \in \{HSL, HS, CS\}$.

For the traditional HS structure, where one squadron is embarked on a carrier, the value of R_i will be 1. If an option i has a shore based HS structure that sends detachments and

supports more than one carrier, the value of R_i will be less than one. The number of carriers supported by one squadron can be derived by taking the inverse of R_i.

The number of aircraft carriers stationed at each geographic region is entered into the model and the total number of squadrons required is computed by the following equation:

$$SR_{i,g} = CV_g * R_i \qquad (11)$$

where: $SR_{i,g}$ is the total number of squadrons required in geographic region g for option i, for i=1,...,5 and $g \in \{W,E,H,J\}$

R_i is defined above

CV_i is the number of carriers stationed in geographic region g, for $g \in \{W,E,H,J\}$

Since fractional requirement cannot be met by the partitioning of squadrons, a more realistic expression is computed by

$$SR'_{i,g} = \lceil SR_{i,g} \rceil \qquad (12)$$

where: $SR_{i,g}$ is defined above

$\lceil x \rceil$ is the smallest integer $\geq x$.

To illustrate how Equations 11 and 12 work, let $R_i = 0.5$ squadrons per carrier and CV_g = 3 carriers. This corresponds to a situation in which three carriers are stationed in geographic region g and a squadron can support two carriers ($1/R_i = 2$). Equation 11 yields a value 1.5 squadrons for $SR_{i,g}$, which is the number of squadrons needed in region g. A half squadron requirement will be filled by an entire squadron, since fractions of squadrons are not based in different locations. Equation 12 gives a value of 2 for $SR'_{i,g}$, signifying that two squadrons are needed to meet the requirement for region g.

The measure of how well option i, is able to meet HS overseas basing requirements, HSR_i, is computed as follows:

$$HSR_i = \min\left(1, \frac{T_{i,t}}{\sum_g SR'_{i,g}}\right) \tag{13}$$

where: $SR'_{i,g}$ is the total number of squadrons required in geographic region g for option i, for i=1,...,5 and $g \in \{W,E,H,J\}$

$T_{i,t}$ is the total number of squadrons of type t for option i, for i=1,...,5 and $t \in \{HS, CS\}$.

This gives the degree to which an option can meet the basing requirements, with a value of 1 signifying that the option can meet or exceed the requirement. For example, if an option meets or exceeds the requirement, the value returned would equal 1. If an option can only meet 80% of the requirement, then the value returned would equal 0.8.

b. HSL Overseas Basing Requirements

A binary variable denoted $LAMPS_g$ is entered into the model to identify geographic regions where HSL squadrons are presently stationed. If a squadron is based in region g it is represented by a 1, else $LAMPS_g$ takes on the value 0. For options that include traditional HSL squadrons, the number of HSL squadrons per region for option i, HSL_i, is determined by

$$HSL_i = \frac{T_{i,HSL}}{\sum_g LAMPS_g} \tag{14}$$

where: $T_{i,HSL}$ is the total number of HSL squadrons for option i, i=1,...,5

$LAMPS_g$ is the binary geographic location indicator described above, for $g \in \{W,E,H,J\}$

A value of 1.0 or greater indicates that the requirement can be met.

A single HS squadron cannot adequately meet both HS and HSL requirements. Therefore, for options that do not include HSL squadrons, it is necessary to identify geographic regions that have HSL requirements and one or less HS squadrons assigned. This is accomplished with the following equation:

$$LR = \sum_{g} I\left(LAMPS_g - CV_g\right) \tag{15}$$

where:

	LR	is the total number of geographic regions with HSL requirements and one or less HS squadrons assigned
	$LAMPS_g$	is defined above
	CV_g	is the number of carriers station in geographic region g, for $g \in \{W,E,H,J\}$
	$I(x)$	is a function that returns a 1 if $x \geq 0$, and a 0 if $x < 0$.

The ability of option i to meet HSL requirements, $HSLR_i$, is evaluated by combining Equations 13, 14 and 15 as follows:

$$HSLR_i = \min\left(1, HSL_i + \left(1 - Y_{i,HSL}\right) * \left(\frac{T_{i,HS}}{LR + \sum_{g} SR'_{i,g}}\right)\right) \tag{16}$$

where:

	$T_{i,HS}$	is the total number of HS squadrons for option i, for i=1,...,5
	HSL_i	is defined above
	$Y_{i,HSL}$	is a binary variable that takes on the values 0 if the total number of HSL squadrons for option i is 0, and 1 if the total number is 1 or greater, for i=1,...,5
	LR	is defined above
	$SR'_{i,g}$	is defined above.

Like Equation 13, the value returned is a measure of the degree to which an option can meet the basing requirements, with the ability to meet or exceed the requirement set at 1.

C. RESULT MATRIX

The criteria are calculated for all five options and the results displayed in 8x5 matrix. Options are represented by columns and the criteria by rows. An example of the resulting matrix is presented in Table 2. The first three options are from the Big Sky proposal. Two additional options for HS/HSL consolidation, 4 and 5, have been included for the purpose of demonstrating the model. Option 4, called the "All Det" option, consists of ten HH-60H helicopters. The fifth option, referred to as the "Functional

Structure", consists of ten HS squadrons with four HH-60Hs per squadron and ten HSL squadrons with ten SH-60Rs per squadron.

Rows 1 through 5 contain the results of the first five criteria: command opportunity, efficient use of LAMPS assets, carrier helicopter requirements, manpower costs and detachment separation time. Rows 6 and 7 show the HSL and HS overseas basing requirement criteria. A composite overseas basing score, the mean of rows 6 and 7, is presented in row 8 and, together with the first five criteria, will be used for option evaluation and comparison. Rows 6 and 7 are added to show how well an option meets the individual requirements.

CRITERION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	16	12	10	14	20
Total Coverage	22646	22646	18117	22646	22646
Manpower Costs	167.6	153.6	133.5	173.2	170.7
CV Helo Availability	64	64	96	64	64
Detachment Separation Time	0	12	6	0	0
Forward Basing - HSL	1	0	1	1	0
Forward Basing - HS	1	1	1	0.8	1
Total Forward Basing	1	0.75	0.92	0.9	1

Table 2. Results Matrix.

The criteria can be divided into two separate categories. The first, which includes command opportunity, efficient use of LAMPS assets, carrier helicopter availability and ability to meet forward basing requirements, are criteria we seek to maximize. The second consists of detachment separation time and manpower costs, criteria we seek to minimize. The minimize criteria are transformed into maximize criteria by taking the inverse of the values obtained since $\min(x_i) = \max(1/x_i)$. The resulting matrix contains only maximize criteria.

The units of measure are not uniform across criteria. For example, command opportunity is measured in command billets, while the efficiency of LAMPS asset use is in square miles per day. Also, as Table 2 shows, there is considerable disparity in the scale

of measure for the different criteria. This makes option comparison across criteria difficult. To simplify the results matrix each value is modified as follows:

$$a_{ij} = \frac{a_{ij}}{\max\limits_{i}\left(a_{ij}\right)} \quad \text{for } i=1,\ldots,6 \text{ and } j=1,\ldots,5 \qquad (17)$$

where a_{ij} is the value of criteria i for option j, and $a_{ij} = [0,1]$. The maximum value in a row is selected, and all the values in that row are divided by that value, resulting in unit cancellation. Each a'_{ij} value is a measure of the relative performance of an option, with the maximum value obtained for an attribute as the upper bound. The result is a matrix where all the values fall in the interval [0,1]. Since the matrix has been transformed to contain only maximize criteria, we seek options where a'_{ij} is greatest. It is important to note that removal or addition of an option may change the matrix by changing the maximum a'_{ij}. However, the measure of relative performance between options will be conserved.

Rows 6 and 7 from the initial matrix are not included in the modified version, since the two rows are combined into a composite overseas basing score. An example of the modified results matrix is included in Table 3. It is this matrix that is used by the model for option comparison.

CRITERION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	0.8	0.6	0.5	0.7	1
Total Coverage	1	1	0.8	1	1
Manpower Costs	0.8	0.87	1	0.77	0.78
CV Helo Availability	0.67	0.67	1	0.67	0.67
Detachment Separation Time	1	1	0.5	1	1
Total Forward Basing	1	0.75	0.92	0.9	1

Table 3. Modified Results Matrix.

III. DECISION ANALYSIS

In this chapter, decision analysis is applied to the model. The use of a trade-off weight in the command opportunity equation to assess the relative importance of carrier-based commands over non-carrier commands is discussed. Also, the selection and application of weights to allow the evaluation of different options across criteria is developed.

A. COMMAND OPPORTUNITY WEIGHT

As discussed in Chapter II, retaining squadron commands on the carrier is considered very important by both the HS and HSL communities. Commands on a carrier are viewed as an important path to flag rank, and their loss could further isolate the helicopter community from the tactical air community. A trade-off weight w is used to express the desirability of a carrier squadron command over a non-carrier command.

Equation 1 measures the total command opportunity an option represents. The number of HSL and shore-based HS squadrons for each option are counted and expressed in non-carrier command billets. Traditional HS squadrons are counted for each option and this number is expressed in carrier command billets. This number is multiplied by the trade-off weight w that is expressed in non-carrier command billets per carrier command billets. Equation 1 combines these expressions and provides a measure of command opportunity in equivalent non-carrier command billets.

The weight w represents the number of non-carrier squadron command billets a decision maker is willing to give up for an additional carrier-based squadron command billet. In other words, w shows the relative value of shore-based commands versus sea-based commands. This trade-off weight must be determined by the decision maker and is directly related to the relative importance attributed to carrier-based squadron commands.

To determine the value of w, the decision maker must decide on the number of non-carrier commands he is willing to give up to obtain one carrier-based command. For example, if a decision maker is willing to give up two non-carrier commands for an

additional carrier command, then the value of w will be 2.0. If he is indifferent between the two types of commands, the value of w would equal 1.0.

It is possible to determine which option yields the optimal number of equivalent non-carrier command billets for a given value of w. For each option i, the number of equivalent non-carrier command billets as a function of w is given by $v_i(w) = a_i + b_i w$ where a_i is the total number of shore-based commands and b_i is the total number of sea-based commands for option i. Values of a_i and b_i for the five options considered in the model are presented in Table 4.

OPTIONS	NON-CARRIER COMMANDS a	CARRIER COMMANDS b
1	6	10
2	2	10
3	0	10
4	14	0
5	10	10

Table 4. Equivalent Non-Carrier Command Data.

For a given value of w, we are interested in the option that maximizes the function v(w). Results for the five options considered are presented graphically in Figure 2.

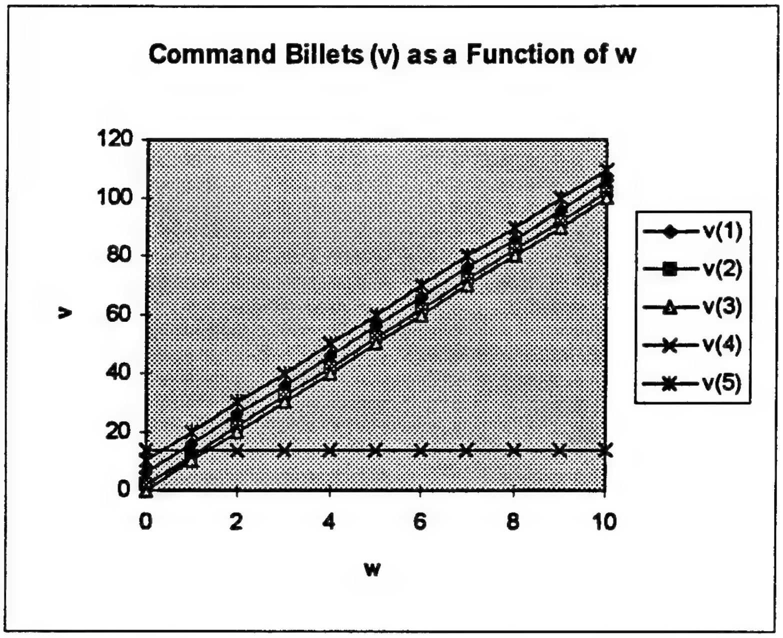


Figure 2. Equivalent Shore-Based Commands (v) as a Function of Weight w.

The optimal equivalent non-carrier command billets function v*(w) is given by

$$v^*(w) = 14 \qquad \text{if } w < 0.4,$$

$$v^*(w) = 10+10w \qquad \text{if } w > 0.4.$$

For values of w less than 0.4, option 4 is optimal. If the value of w exceeds 0.4, option 5 represents the optimal solution. Since carrier-based commands are considered more attractive than non-carrier commands, the value attributed to w should be greater than 1.0 and option 5 represents the optional solution.

B. CRITERIA WEIGHTS

A decision maker is presented with a modified results matrix that shows the relative performance of an option for each of the six criteria. To simplify the task of evaluating the options and selecting the optimal one, values for the criteria must be combined. This is accomplished by developing a set of weights to determine the relative importance a decision maker attributes to each criterion.

In the model, manpower costs are considered a constraint rather than an objective. A decision maker is not concerned with minimizing cost, he is concerned with maximizing overall effectiveness for a given budget. Therefore, the number of criteria evaluated by the model to determine the optimal solution is reduced from six to five; command opportunity, efficient use of HSL assets, CV helicopter requirements, detachment separation time and forward basing requirements. These five criteria collectively measure the level of effectiveness achieved by an option.

An example of the matrix used by the model to compute the effectiveness of the options evaluated is shown in Table 5.

CRITERION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	0.8	0.6	0.5	0.7	1
Total Coverage	1	1	0.8	1	1
CV Helo Availability	0.67	0.67	1	0.67	0.67
Detachment Separation Time	1	1	0.5	1	1
Total Forward Basing	1	0.75	0.92	0.9	1

Table 5. Effectiveness Matrix.

It differs from the modified results matrix presented in Table 3 in that the row for manpower cost is omitted. If the manpower constraint is ignored, it is possible to reduce the number of options a decision maker must evaluate for the set of options considered from Table 5. Options 1, 2, 4 and 5 achieve the same value for criteria 2 and 4. For the remaining three criteria, 1, 3 and 5, option 5 achieves a greater value. Therefore, option 5 is always optimal with respect to options 1,2 and 4. The decision maker need only concern himself with options 3 and 5, since these two make up the set of potential optimal solutions.

The decision maker is asked to assume that the five criteria are at a hypothetically "worst" level. The model then provides the decision maker with a fixed budget that allows improvement of the criteria from worst to best. He is asked to distribute the

budget among the five criteria. The distribution of the budget should reflect the relative importance attributed by the decision maker to each of the five criteria considered.

The result of the budget distribution is used to construct a weight vector **w** $=(w_1,w_2,w_3,w_4,w_5)$, where w_i represents the weight attributed to criterion i for i=1,2,...,5, and

$$\sum_{i=1}^{5} w_i = 1. \qquad (18)$$

The weight vector is applied to the results matrix and an effectiveness value V_j is computed for option j by

$$V_j = \sum_{i=1}^{5} w_i a_{ij} \qquad \text{for } i=1,2,\ldots,5 \text{ and } j=1,2,\ldots,5 \qquad (19)$$

where a_{ij} is described in Equation 17. The option that achieves the greatest value for V_j represents the optimal solution.

It is not possible to represent graphically which option yields the greatest value of V_j for a given **w** because this would require a four dimensional graph. However, if we set two of the w_i's equal to 0, the remaining three w_i's can be displayed graphically. For example, we set w_4 and w_5 equal to 0. Since, from Equation 18, the remaining w_i's (w_1,w_2,w_3) must sum to 1, we can write $w_3 = 1 - w_1 - w_2$. A graph of the region of feasible w_i's is a triangle with corner points (1,0), (0,0), (0,1) representing $w_1=1$, $w_2=1$ and $w_3=1$ respectively (Marshall and Oliver, 1994, p. 400). An example of this graph is presented in Figure 3. The labeled shaded regions of the triangle represent values of w_1, w_2 and w_3 for which a specific option is optimal.

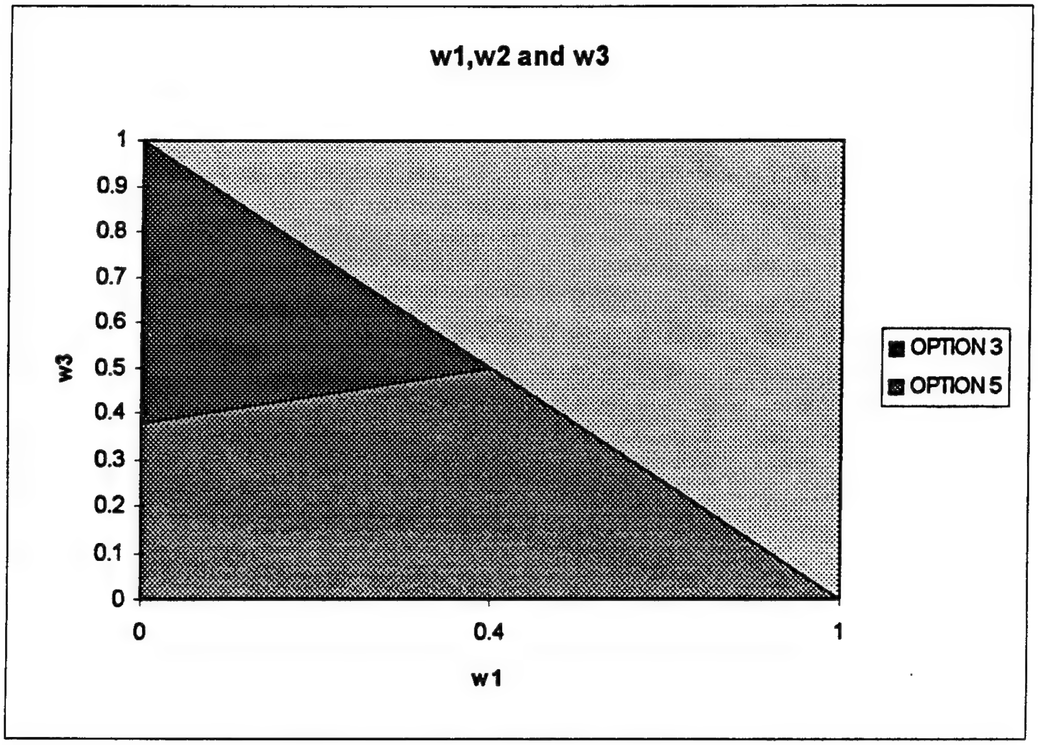


Figure 3. w_1,w_2,w_3 with w_4 and $w_5 = 0$.

There are ten different combinations of five weights taken three at a time. Since option 5 achieves values greater than option 3 for all criteria except CV helicopter requirements, we need consider only those combinations that include w_3. This reduces the combinations of interest from ten to six. The graph for w_1,w_2 and w_3 is shown above in Figure 3. The remaining five graphs are presented in Appendix A. From the graphs it can be seen that option 3's optimal regions are smaller than options 5's and restricted to values of w_3 close to 1. Larger values for w_1 and w_4 significantly favor option 5, while increasing the values of w_2 and w_5 increase option 3's optimal region. Although it is difficult to determine how all five weights interact, these graphs help in identifying which weights increase an option's optimal region.

Although the ideal choice is the option which achieves the greatest level of effectiveness, the decision maker must select the option which also meets the budgetary constraint. The relationship between the level of effectiveness an option achieves and its associated manpower cost must be examined. The effectiveness for a given **w** is computed for each option and plotted against the associated manpower cost. Figure 4 is an example of such a graph with a weight vector where $w_1 = w_2 = w_3 = w_4 = w_5$.

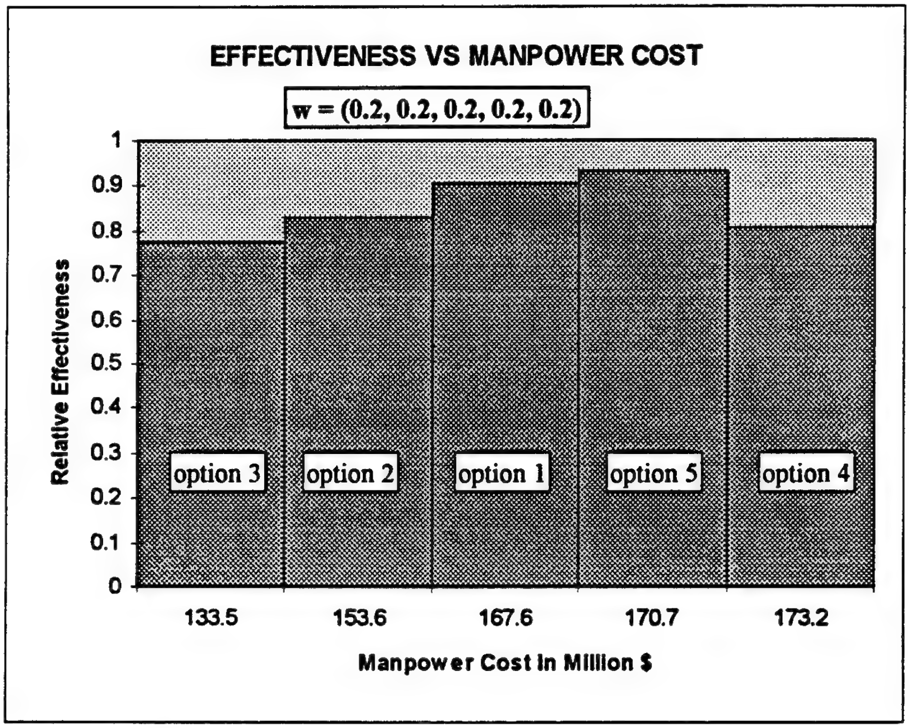


Figure 4. Effectiveness versus Manpower Cost.

Each manpower cost on the horizontal axis corresponds to one of the five options, for example, 133.5 and 153.6 are the costs in millions of dollars associated with options 3 and 2 respectively. The graph allows a decision maker to determine which option yields the greatest level of effectiveness for a given cost constrain. Given a fixed budget, the decision maker selects the option that achieves the maximum level of effectiveness for a manpower cost equal to or less than the budget.

Plotting effectiveness for a given weight vector **w** versus manpower cost is also a useful tool in analyzing the effect differing the weight elements in the weight vector has on overall effectiveness. It is noted above that large values of w_1 and w_4 lead to selection of option 5 as the optimal choice, while larger values of w_2 and w_5 increase option 3's optimal region. Also, a value of w_3 close to 1 makes option 3 the optimal solution. This relationship is confirmed when the plots for two different weight vectors are compared. In Figure 5, effectiveness computed with a weight vector $\mathbf{w} = (0.3, 0.15, 0.1, 0.3, 0.15)$ is plotted against manpower cost. The values attributed to w_1 and w_4 are significantly larger than those of the other weight elements.

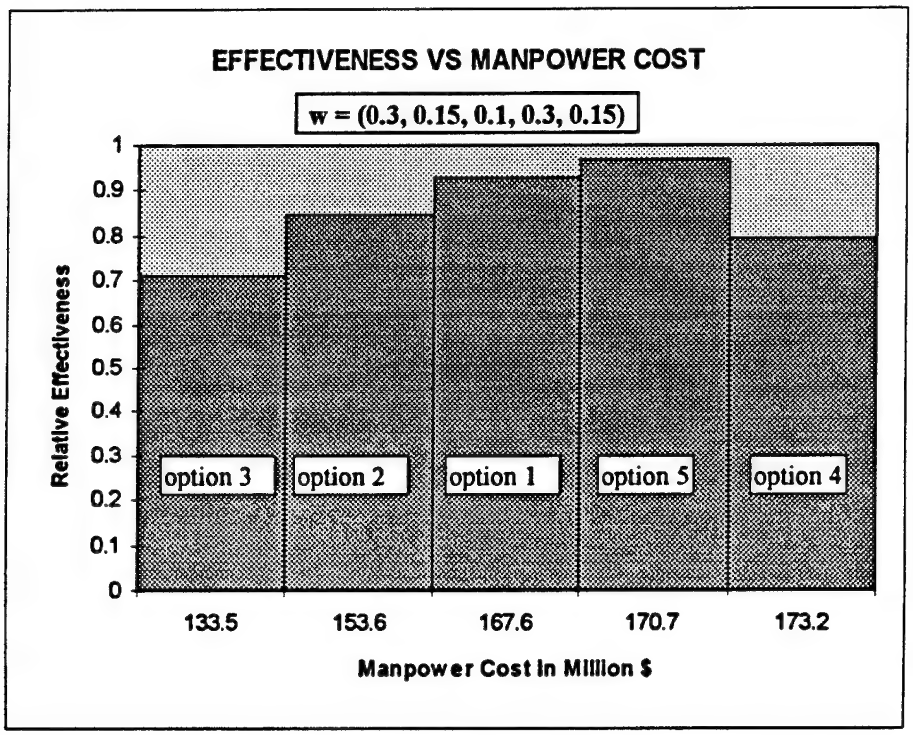


Figure 5. Effectiveness versus Manpower Cost.

Compare the results from Figure 5 to those of Figure 6 below, where w_2 and w_5 are favored over w_1 and w_4 with $\mathbf{w} = (0.1, 0.35, 0.1, 0.1, 0.35)$. Note that w_3 is held constant to study the relationship between the two sets of weight elements.

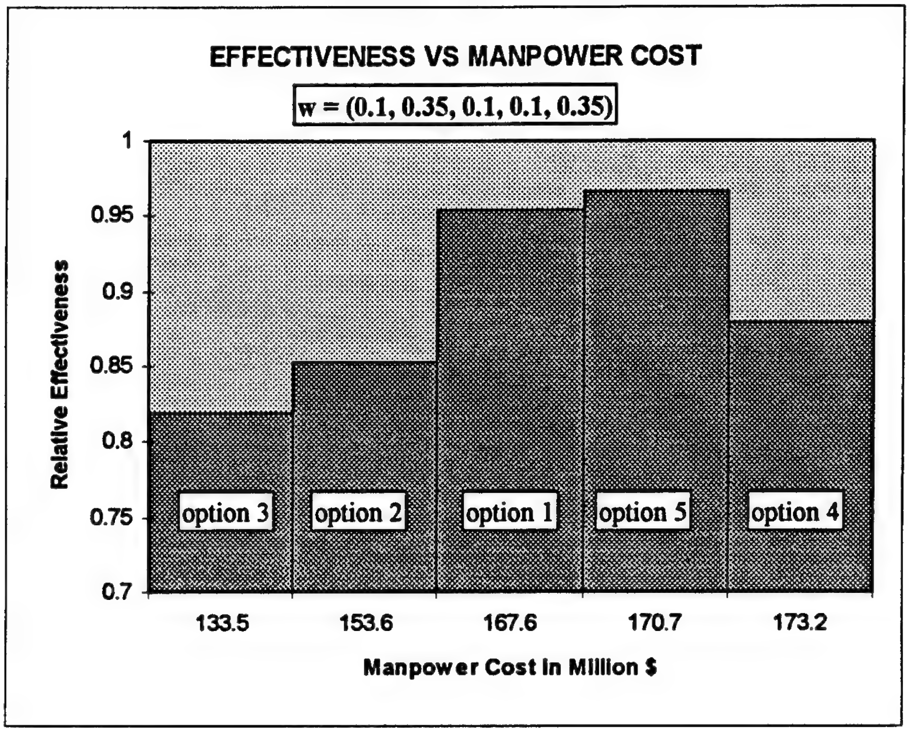


Figure 6. Effectiveness versus Manpower Cost.

In both situations, option 5 achieves the greatest level of effectiveness and option 3 achieves the lowest. However, the difference between options 5 and 3 decreases as w_2 and w_5 become larger with respect to w_1 and w_4. The difference in effectiveness between option 3 and 5 is 0.309 in Figure 5, and a substantially lower 0.165 in Figure 6.

Next, we consider a weight vector where w_3 is given a value of 0.5 while w_2 and w_5 have values greater than w_1 and w_4. We expect the effectiveness of option 3 to increase significantly with respect to option 5. Figure 7 gives the results of a weight vector $\mathbf{w} = (0.05, 0.2, 0.5, 0.05, 0.2)$.

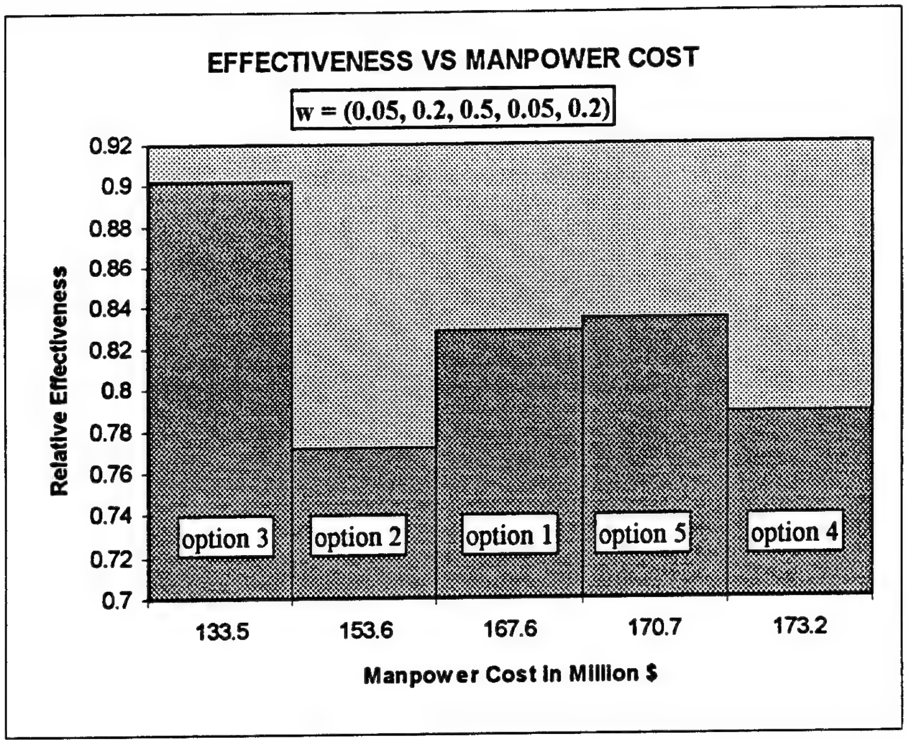


Figure 7. Effectiveness versus Manpower Cost.

The maximum effectiveness is achieved by option 3. Since option 3 is the least expensive option from a manpower cost perspective, it also represents the overall optimal solution regardless of the cost constraint imposed, assuming a cost constraint will not be less than 133.5 million dollars. Holding w_3 constant, we give values to w_1 and w_4 greater than those of w_2 and w_5 by exchanging the values so that $\mathbf{w} = (0.2, 0.05, 0.5, 0.2, 0.05)$. Option 5 now achieves the greatest effectiveness level, as shown in Figure 8.

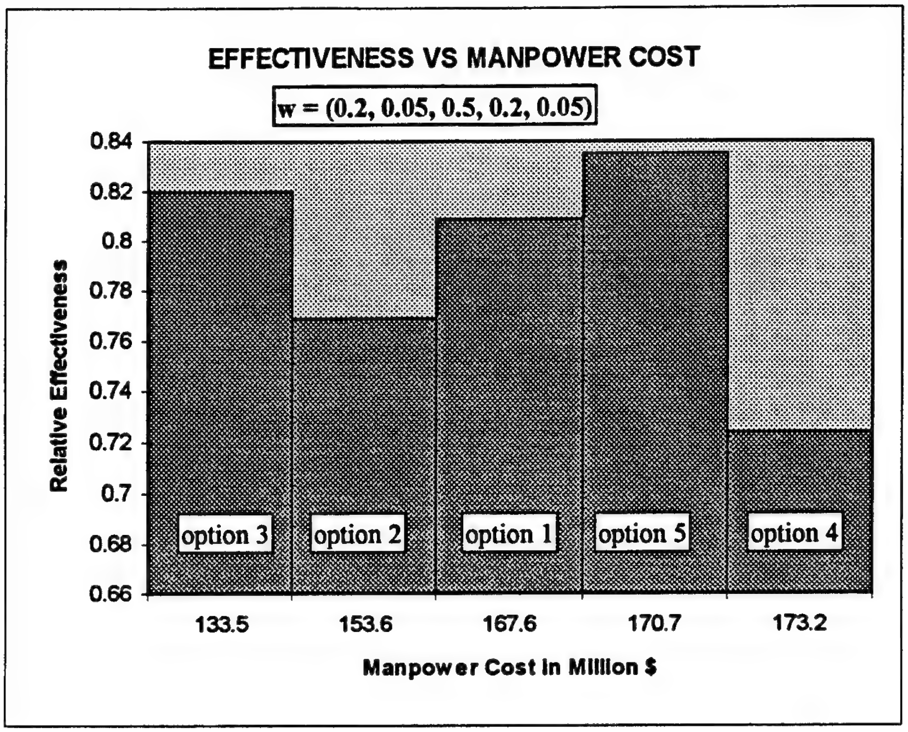


Figure 8. Effectiveness versus Manpower Cost.

It is important to note that for all the examples examined above, option 5 achieves values of effectiveness greater than options 1,2 and 4. Given that option 4 has a higher manpower cost than option 5, we can exclude option 4 from consideration. Options 1 and 2 can not be excluded since their manpower costs are lower than option 5's, and the option selected is also determined by the given cost constraint.

IV. MODEL DEMONSTRATION

This chapter presents a sample run of the model to demonstrate its structure and how a decision maker may use it as a tool in evaluating a set of options for HS/HSL consolidation. The model is implemented on a Microsoft Excel version 5.0 workbook. The workbook contains four sheets; options, data, weights, and results. The sample run of the model is included in Appendix B.

A. OPTIONS

Information about the options evaluated is entered into the first sheet of the workbook. Titled "Options", this sheet contains a table that provides space for the evaluation of five options per model run. Each option is entered into the table by column. The rows break down an option by number and types of squadrons contained, number and type of helicopters assigned to each squadron type, and the number and type of helicopters assigned to the aircraft carriers. The manpower cost for each option is entered into the final row of the table. The completed table for this run of the model is shown in Table 6. The options evaluated in this demonstration run of the model are the five introduced in Chapter I.

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
# HSL SQUADRONS	6	2	0	10	10
SH-60R's per squad.	10	20	0	10	10
HH-60H's per squad.	0	0	0	0	0
# CV SQUADRONS	10	10	10	0	10
SH-60R's per squad.	4	6	10	0	0
HH-60H's per squad.	4	4	4	0	4
SH-60R's on CV	0	0	2	0	0
HH-60H's on CV	4	4	4	0	4
# CV(S) SQUADRONS	0	0	0	4	0
SH-60R's per squad.	0	0	0	0	0
HH-60H's per squad.	0	0	0	10	0
SH-60R's on CV	0	0	0	0	0
HH-60H's on CV	0	0	0	4	0
MANPOWER COST	167.6	153.6	133.5	173.2	170.7

Table 6. Options Evaluated in Model Run.

The model automatically checks for the occurrence of common input errors. The number of each type of helicopter in each option is counted, displayed and compared to the total number of helicopters available in the inventory, which is entered in the helicopter data table in the second sheet of the model. If an "OK" flag is displayed, the numbers match. Discrepancies are identified by an "ERROR" flag. The options sheet also contains shaded tables displaying calculations performed by the model for use by other sheets. These tables require no input from the decision maker.

B. DATA

The second sheet, titled "Data", is for input of additional information not directly related to the options, but required by the model to compute criterion values. Tables are provided for the input of helicopter, ship, sensor and geographic location data. Shaded tables, as in the options sheet, display the results of computations performed by the model.

The helicopter data used for the demonstration run is shown in Table 7.

	SH-60R	HH-60H
Speed	70	70
FMC rate	0.8	0.8
Max flight hours	20	20
Total A/C in inventory	100	40

Table 7. Helicopter Data.

Speed is the helicopter's maximum endurance airspeed. The FMC rate is the proportion of time a helicopter is in a full mission capable status. Max flight hours is the maximum number of flight hours a helicopter can fly in a 24 hour period. The total number helicopters in the inventory used in this model run corresponds to the numbers used in the development of the Big Sky consolidation proposals.

The ship data used is shown in Table 8. The ship numbers are derived from a helicopter community brief (Squires, 1994) that estimates 97 LAMPS capable ships and ten active duty aircraft carriers will be in the Navy's inventory for the time frame in which

the HS/HSL consolidation is projected to take place. All 97 LAMPS capable ships are assumed to be dual rail because the newer ships have the capability to handle two aircraft, and the older single rail ships will be decommissioning in the near future. Surge rate represents the maximum fraction of all ships in the Navy that can be put to sea in a time of crisis. Values of 0.7 for surface combatants and 0.6 for carriers are selected as reasonable estimates.

	Single Rail	Dual Rail	CV
Total in Inventory	0	97	10
Surge Rate	0.7	0.7	0.6

Table 8. Ship Data.

For the sensor data, 0.25, 0.50 and 0.25 are entered as the probability of being tasked to search for a small, medium or large sized target respectively. The model checks to ensure that the three probability values sum to one. Surface-search radar ranges of 20 miles for a small target, 40 miles for a medium target and 80 miles for a large sized target are used.

Four geographic regions where squadrons can be stationed are recognized by the model; the Atlantic, Pacific, Hawaii and Japan. The location of HSL and HS squadrons used in this demonstration of the model reflect the current distribution of assets, and is shown in Table 9 below.

GEOGRAPHIC DATA			
	HSL	CV	# of CV's
Atlantic	1	1	4
Pacific	1	1	5
Hawaii	1	0	0
Japan	1	1	1
Totals	4	3	10

CV Check
OK
OK
OK
OK

Table 9. Geographic Data.

The stationing of one or more HS or HSL squadrons in a region is denoted by a 1 in the HS and HSL columns. The next column, CV numbers, shows the number of carriers stationed in each region. The model checks that any non-zero entry in the HS column is matched by a non-zero entry in the CV numbers column. This ensures that HS squadrons are collocated with aircraft carriers.

C. WEIGHTS

A brief explanation of the significance of the trade-off weight used in the command opportunity equation is provided to the decision maker using the model. A weight value of 2.0 non-carrier command billets per carrier command billets is selected for this run of the model. This value signifies that a carrier-based squadron command is equivalent to two shore-based squadron commands.

A brief explanation of the criteria weights is also provided to the user. A budget of 100 units is used to simplify distribution. The model converts the distributed units into weight values that sum to 1.0. For this run of the model, the decision maker determines that command opportunity and total forward basing are the two most important criteria and allocates 40 and 30 units respectively. The remaining three criteria are allocated ten units each.

D. RESULTS

The final sheet contains the results. The initial results matrix for this run of the model is shown in Table 10. It displays criterion values calculated for the five options evaluated. The values contained across a row are in the units of the corresponding criterion. For example, the values for command opportunity are in equivalent non-carrier command billets, and the values for CV helo requirements are in helicopter flight hours per carrier per 24 hour period.

CRITERION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	16	12	10	14	20
Total Coverage	22646	22646	18117	22646	22646
Manpower Costs	167.6	153.6	133.5	173.2	170.7
CV Helo Availability	64	64	96	64	64
Detachment Separation Time	0	12	6	0	0
Forward Basing - HSL	1	0	1	1	0
Forward Basing - CV	1	1	1	0.8	1
Total Forward Basing	1	0.75	0.92	0.9	1

Table 10. Results Matrix.

The modified results matrix, used to compute overall effectiveness, is shown in Table 11.

CRITERION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	0.8	0.6	0.5	0.7	1
Total Coverage	1	1	0.8	1	1
Manpower Costs	0.8	0.87	1	0.77	0.78
CV Helo Availability	0.67	0.67	1	0.67	0.67
Detachment Separation Time	1	1	0.5	1	1
Total Forward Basing	1	0.75	0.92	0.9	1

Table 11. Modified Results Matrix.

An optimality table, shown in Table 12, shows the optimal value achieved for a criterion from the initial results matrix.

RESULTS	O. VALUE	OPTION
Command Opportunity	30	5
Total Coverage	22646	Multi Opts.
Manpower Costs	133.5	1
CV Helo Requirements	96	3
Detachment Separation Time	6	Multi Opts.
Forward Basing	1	Multi Opts.

Table 12. Optimal Criterion Values.

The optimal value is displayed in the O. Value column and the number of the option that achieved it is given in the adjacent Options column. If an optimal value is achieved by more than one option, Mult. Opts. is displayed in the Options column to indicate that multiple options achieved the optimal value for the given criterion.

A weighted total for the five options evaluated in this demonstration run is presented below:

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
WEIGHTED TOTALS	0.915	0.784	0.774	0.725	0.967

It shows the overall effectiveness achieved by each option. Note that the maximum value is achieved by option 5. Therefore, for the set of options evaluated and the weight values selected by the decision maker for this run of the model, option 5 is the optimal choice.

V. CONCLUSIONS

A. SUMMARY

The goal of this thesis is to provide a methodology to evaluate competing options for HS/HSL consolidation. Six issues that could be adversely affected by HS/HSL consolidation are identified; command opportunity, efficient use of LAMPS assets, manpower costs, fulfillment of aircraft carrier helicopter requirements, detachment separation time, and ability to meet forward basing requirements. Appropriate criteria are developed to quantitatively measure the issues. Manpower cost is selected as a constraint, and the remaining five criteria are used to measure effectiveness.

Results are presented in two different tables; an initial results matrix which shows the criteria values achieved by each option, and a modified results matrix which gives the criterion value for an option as a fraction of the maximum achieved. The modified results matrix simplifies option comparison across criteria. The criteria are incorporated into a model that allows a comparison of five consolidation options simultaneous. The model is easily expandable to include a greater number of criteria.

Decision maker participation is required to derive values for the individual weight elements in a criteria weight vector. The weight elements represent the relative importance the decision maker attributes to each criterion. The model utilizes the resulting weight vector to compute which one of the five options evaluated achieves the greatest level of effectiveness.

Five HS/HSL consolidation options are examined; three options from the Big Sky proposal, the All Det option, and the Functional Structure option. Analysis of the modified results matrix shows that the All Det and Functional Structure, options 3 and 5 respectively, make up the set of potential optimal solutions if cost constrains are not considered. Option 5 achieves values greater than option 3 for four of the five criteria. Five different weight vectors are employed to determine the effect changes in weight element values have on option selection. For different criteria weight vectors, option 3's

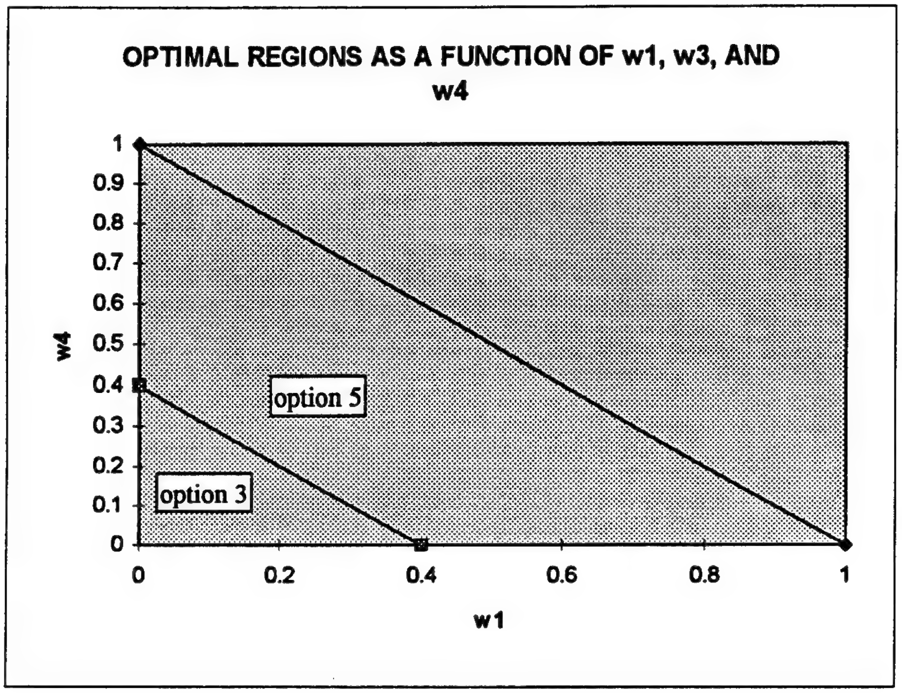
optimal regions are smaller those for option 5. In five model runs using different weight vectors, options 5 achieved the highest effectiveness level in four of the runs.

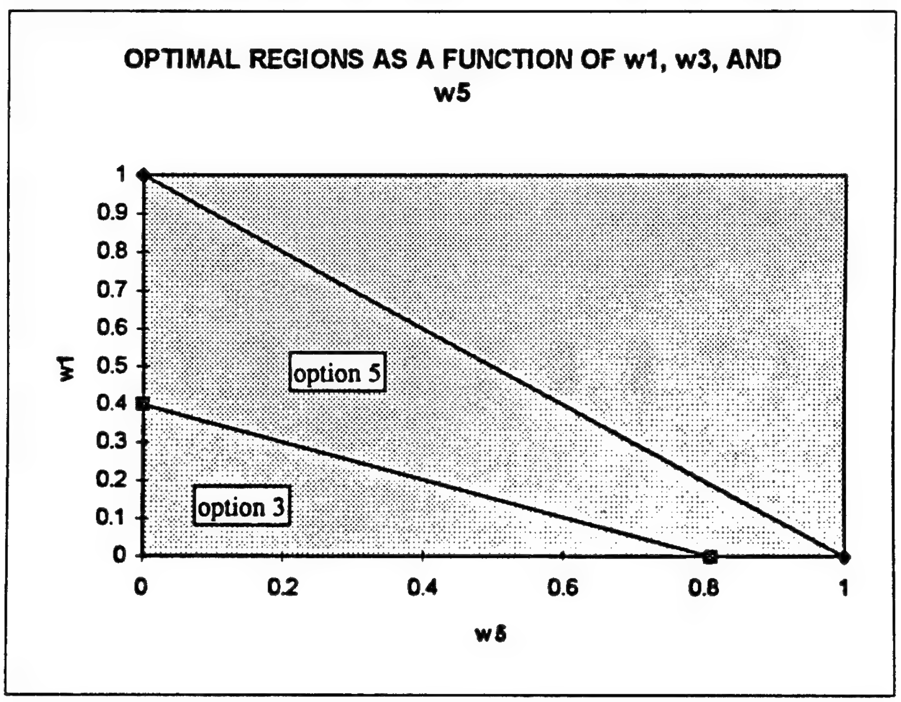
Recognizing that option selection is cost constrained, a plot of option effectiveness versus associated manpower cost provides a useful tool for determining the optimal consolidation option and maximum effectiveness achievable for a given budget. Additionally, the marginal cost associated with improving effectiveness from a set level to the desired level can be determined.

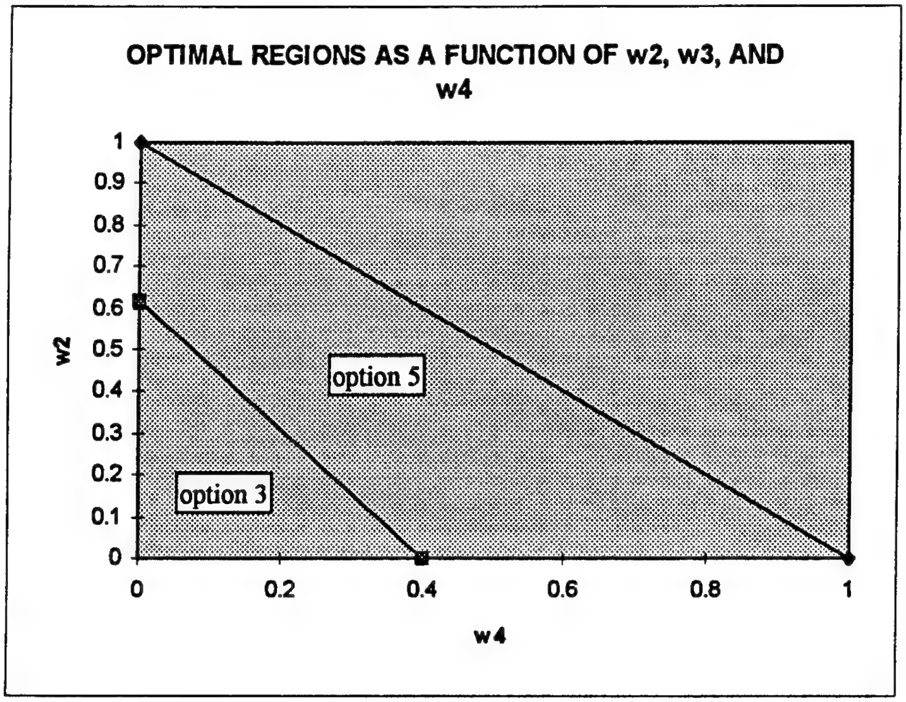
B. RECOMMENDATIONS

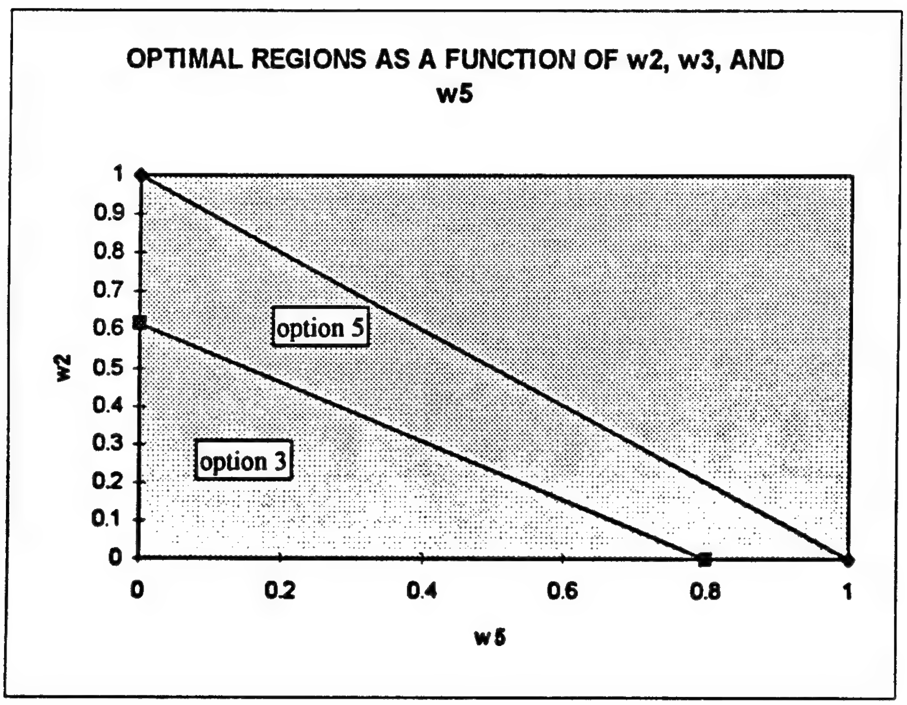
The use of manpower costs as a measure of the relative expense associated with an option can be misleading. Additional costs incurred by an option due to operational shortcoming should be also be considered. The model successfully identifies options that are unable to meet current overseas basing requirements, however, it does not compute the TAD cost for forward deployed detachments needed to support ships stationed overseas. TAD costs for forward deployed detachments have historically been high and could offset or surpass savings in manpower costs. Determining these additional costs would give a more accurate assessment of the cost associated with a consolidation option.

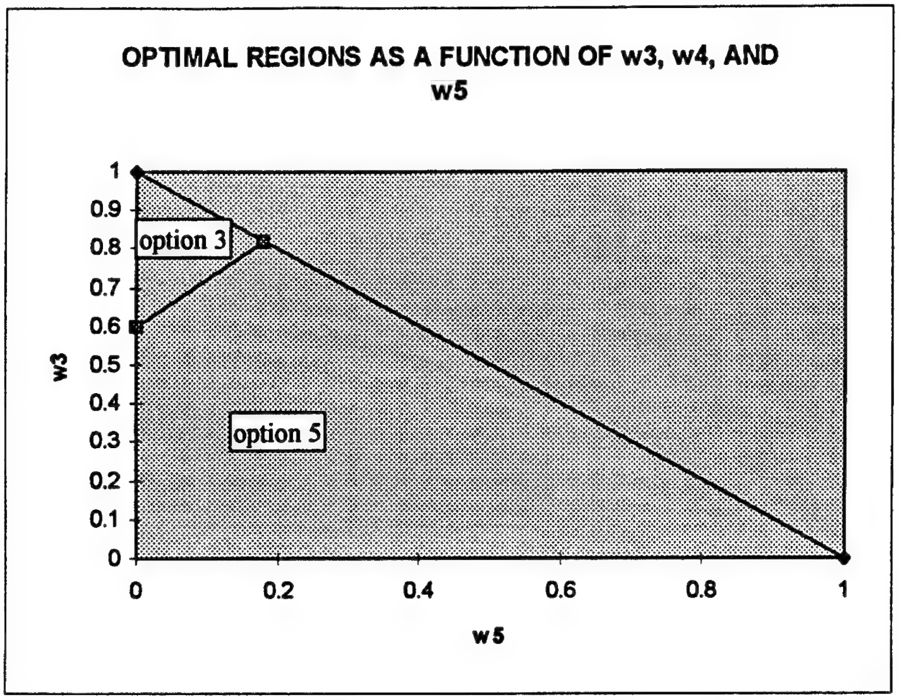
APPENDIX A. GRAPHS OF OPTIMAL REGIONS FOR FEASIBLE VALUES FOR W_i






OPTIMAL REGIONS AS A FUNCTION OF w2, w3, AND w4
option 5
option 3
w2
w4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8


OPTIMAL REGIONS AS A FUNCTION OF w2, w3, AND w5
option 5
option 3
w2
w5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8


OPTIMAL REGIONS AS A FUNCTION OF w3, w4, AND w5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
w3
option 3
option 5
0
0.2
0.4
0.6
0.8
1
w5

APPENDIX B. SAMPLE MODEL RUN

Options Sheet

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
# HSL SQUADRONS	6	2	0	10	10
SH-60R's per squad.	10	20	0	10	10
HH-60H's per squad.	0	0	0	0	0
# CV SQUADRONS	10	10	10	0	10
SH-60R's per squad.	4	6	10	0	0
HH-60H's per squad.	4	4	4	0	4
SH-60R's on CV	0	0	2	0	0
HH-60H's on CV	4	4	4	0	4
# CV(S) SQUADRONS	0	0	0	4	0
SH-60R's per squad.	0	0	0	0	0
HH-60H's per squad.	0	0	0	10	0
SH-60R's on CV	0	0	0	0	0
HH-60H's on CV	0	0	0	4	0
MANPOWER COST	167.6	153.6	133.5	173.2	170.7

TOTAL SH-60R	100	100	100	100	100
CHECK	OK	OK	OK	OK	OK

TOTAL HH-60H	40	40	40	40	40
CHECK	OK	OK	OK	OK	OK

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Binary Variable					
Y(HSL)	1	1	0	1	1
Y(CV)	1	1	1	0	1
Y(CS)	0	0	0	1	0

Detachment Separation					
DS(HSL)	6	6	0	6	6
DS(CV)	0	0	12	0	0
DS(CS)	0	0	0	6	0

Total(of a in s for j)					
R on CV	0	0	20	0	0

H on CV	40	40	40	16	40

Data Sheet

A/C DATA	SH-60R	HH-60H
SPEED	70	70
FMC rate	0.8	0.8
Max Flight hours	20	20
Total A/C in inventory	100	40

SHIP DATA	Single Rail	Dual Rail	CV
Total in Inventory	0	97	10
Surge Rate	0.7	0.7	0.6

	Small	Medium	Large
Target Probability	0.25	0.5	0.25
Radar Range	20	40	80

Pr Check
OK

GEOGRAPHIC DATA	HSL	CV	# of CV's
Atlantic	1	1	4
Pacific	1	1	5
Hawaii	1	0	0
Japan	1	1	1
Totals	4	3	10

CV Check
OK
OK
OK
OK

A/C DATA	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Non CV SH-60R's	100	100	80	100	100
SH-60R available	100	100	80	100	100

SHIP DATA	
Deck Space	135.8

COVERAGE	
Total(small)	1014.15927
Total(medium)	5313.27412
Total(large)	7826.54825
Total Coverage	14153.9816

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
CV SUPPORT R.	1	1	1	0.4	1

GEO. DATA

Atlantic	4	4	4	2	4
Pacific	5	5	5	2	5
Hawaii	0	0	0	0	0
Japan	1	1	1	1	1
Totals	10	10	10	5	10

HSL REQ. CV	
Atlantic	0
Pacific	0
Hawaii	1
Japan	1
Totals	2

Results Sheet

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	16	12	10	14	20
Total Coverage	22646	22646	18117	22646	22646
Manpower Costs	167.6	153.6	133.5	173.2	170.7
CV Helo Availability	64	64	96	64	64
Detachment Separation Time	6	6	12	6	6
Forward Basing - HSL	1	0.5	0.83	1	1
Forward Basing - CV	1	1	1	0.8	1
Total Forward Basing	1	0.75	0.92	0.9	1

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Command Opportunity	0.8	0.6	0.5	0.7	1
Total Coverage	1	1	0.8	1	1
Manpower Costs	0.8	0.87	1	0.77	0.78
CV Helo Availability	0.67	0.67	1	0.67	0.67
Detachment Separation Time	1	1	0.5	1	1

Forward Basing - HSL	1	0.5	0.83	1	1
Forward Basing - CV	1	1	1	0.8	1
Total Forward Basing	1	0.75	0.92	0.9	1

RESULTS	O. VALUE	OPTION
Command Opportunity	20	5
Total Coverage	22646	Multi Opts.
Manpower Costs	133.5	1
CV Helo Requirements	96	3
Detachment Separation Time	6	Multi Opts.
Forward Basing	1	Multi Opts.

WEIGHTED TOTALS	0.967	0.742	0.928	0.877	0.967

OPTIMAL OPTION	5

OPTIMAL VALUE		OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	CHECK 1
20		0	0	0	0	1	1
22646		1	1	0	1	1	4
133.5		0	0	1	0	0	1
96		0	0	1	0	0	1
6		1	1	0	1	1	4
1		1	0	0	1	1	3
1		1	1	1	0	1	4
1		1	0	0	0	1	2
	TOTAL	3	2	2	2	4	
	MAX	4					
	NORM	0.75	0.5	0.5	0.5	1	
	CHECK	0	0	0	0	1	
	SUM	1					
	IDENT	0	0	0	0	5	
	MAX 2	5					

OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5		OPTIMAL
0	0	0	0	5		5
1	2	0	4	5		5
0	0	1	0	0		1
0	0	3	0	0		3
1	2	0	4	5		5
1	0	0	4	5		5
1	1	1	0	1		1
1	0	0	0	1		1

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